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ORIGINAL PAPER

Bilateral decompression using a unilateral pedicle construct for lumbar stenosis

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Abstract
Purpose To determine the effectiveness of bilateral decompression via a unilateral approach using unilateral pedicle screw fixation for two-level lumbar stenosis with instability.
Methods Between October 2006 and October 2010, 98 patients (61 men and 37 women) who had reached the three-year follow-up interval were treated with unilateral pedicle screw fixation at the authors' institution. All patients underwent two-level transforaminal lumbar interbody fusion (TLIF), and the mean age was 59.6 years (range, 40–72). Visual analog scale (VAS) scores and Oswestry Disability Index (ODI) were used to assess the pre-operative and postoperative clinical results. Fusion status, the disc space height, and the whole lumbar lordotic angle were analysed for the radiological evaluation.
Results The ODI scores decreased significantly in both early and late follow-up evaluations and the visual analog scale (VAS) score demonstrated significant improvement in late follow-up ($P<0.01$). The disc space height ($P<0.05$) and the whole lumbar lordotic angle ($P<0.05$) were increased at the final follow-up. Successful fusion was achieved in all patients.
Conclusion Bilateral decompression via a unilateral approach using unilateral pedicle screw fixation for two-level lumbar stenosis with instability, which can maintain the lumbar lordosis and the disc space height, is an effective and less invasive method than with bilateral constructs.

Keywords Unilateral · Transforaminal lumbar interbody fusion · Lumbar stenosis · Invasive

Drs Mao and Li contributed equally to this study.

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Introduction

Bilateral pedicle screw fixations (BPSF) are the standard method of instrumentation for providing rigid lumbar fixation [1, 2]. However, due to the excessive rigidity of the system, this construct is suspected to cause degeneration of adjacent segments. Furthermore, increased morbidity, complications, and re-operation rate must be considered, plus the reasonable doubt arising from the associated cost benefits of instrumentation. To compensate for such shortcomings, several authors report that unilateral pedicle fixations (UPSF) may be as effective as bilateral constructs. Kabins et al. [3] and Suk et al. [4] report that the clinical results of UPSF were nearly identical with that of bilateral fixation. Recently, Mao et al. [5] and Zhao et al. [6] demonstrated that TLIF with UPSF was an effective and convenient method of treatment of single-level lumbar degenerative disease. Zhang et al. [7] have suggested that UPSF with reliable anterior support can be used in two-level lumbar disease.

However, to our knowledge, only studies with a small sample size and short follow-up have been reported for this type of fixation [4–7]. Currently, no studies have reported bilateral decompression via a unilateral approach in the management of two-level lumbar stenosis with instability. The purpose of this retrospective study was to assess the clinical and radiographic results of UPSF with diagonal cage-instrumented TLIF in the management of two-level lumbar stenosis with instability. This study reports the outcomes of 98 patients who had reached the three year follow-up interval.

Materials and methods

Ethics statement

Informed consent was obtained from all participants prior to examination, and ethical approval to undertake this study was

obtained from Human Research Ethics Committee, Shanghai Ninth People's Hospital. We have obtained informed consent from all participants involved in our study. Also, the written consent was given by the patients for their information to be stored in Shanghai Ninth People's Hospital database.

Patients

Between October 2006 and October 2010, 98 patients (61 men and 37 women) who were refractory to adequate conservative treatment and had reached the three-year follow-up interval were treated with bilateral decompression via a unilateral approach using UPSF at the authors' institution. All patients underwent bilateral decompression via a unilateral approach, and the mean age was 59.6 years (range,48–72). Indications for surgery were: (i) severe spinal stenosis with instability (Figs. 1, 2 and 3), (ii) symptoms of neurogenic claudication referable to the lumbar spine, (iii) failure of conservative measures for a minimum of three months. Exclusion criteria were as follows: (i) history of addiction to alcohol or tobacco or any other major psychopathology, (ii) previous operation on the lumbar spine, (iii) other spinal pathologic conditions, including spondylolisthesis, scoliosis or infection, osteopenia, adjacent level degeneration, or gross obesity, and (iv) workers' compensation claims.

Fig. 1 MRI of a 66-year-old woman with two-lever lumbar stenosis (L4/L5,L5/S1) who had failure of conservative measures for a minimum of three months

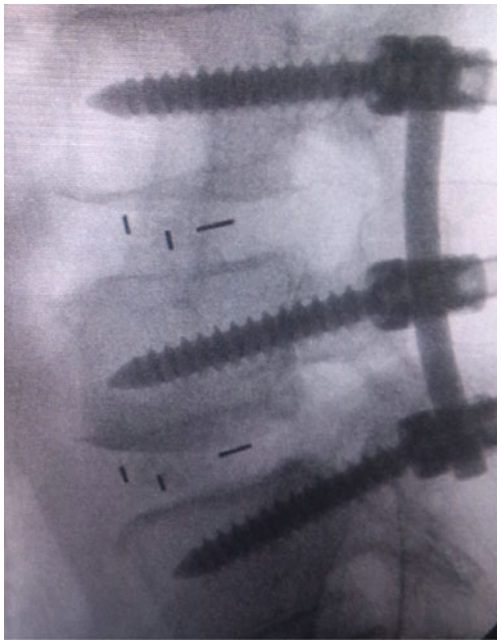

Fig. 2 C-arm lateral image intensifier showing well-positioned cage and pedicle screw in operation

Surgical technique

A single surgeon (J. Zhao) performed the surgeries. The patient was placed in the prone position on a radiolucent table. General anaesthesia was used. The unilateral paravertebral muscles on the symptomatic side were split and retracted laterally to the outer edge of the facet joint, and the lamina and facet joint were exposed. The desired pedicle screw was inserted into the vertebral body. According to the standard TLIF procedure, the inferior and superior articular processes and part of the vertebral lamina were removed, and the nerve root was decompressed. After thorough discectomy and endplate preparation were performed, autologous bone was packed into the anterior disc space, and the polyetheretherketone (PEEK) z-cage (Weigao), which was filled with the morselized bone from the facetectomy and laminectomy, was inserted obliquely into the disk space, and the anterior part of the cage should cross the midline of the vertebral body to support the contralateral part of the anterior column (Figs. 4 and 5). After undercutting the base of the spinous process, the space between the contralateral dural and ligamentum flavum was divided. Then, the contralateral ligamentum flavum and the hypertrophied medial facet were partially removed. The lateral recess and neural foramina were decompressed contralaterally. This is done sequentially until the nerve root at the operative level is seen exiting freely into the foramen. Both the ipsilateral and contralateral nerve roots are well visualized after the bilateral decompression. The screws were connected with rod applying compressive force for better contact of the cage with the endplate and set screws were tightened. The wound was irrigated with saline, and

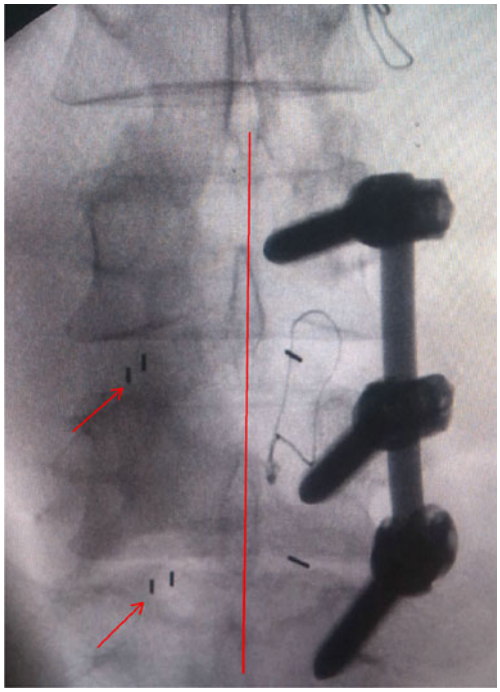

Fig. 3 *Arrows* in the figure indicate well-positioned cage cross the midline of the vertebral body to support the contralateral part of the anterior column. *Straight line* indicates spinal midline

drains were placed as needed. An exercise program was started after one week to strengthen the paravertebral muscles and the patient was advised to return to daily activities after two weeks.

Clinical and radiological assessment

Clinical outcomes were analyzed using the VAS and ODI scores pre-operatively and immediately, at three and six months, and annually thereafter by an independent assessor. Radiological evaluation was judged by two experienced radiologists who were blinded to the clinical outcome and had not taken part in any other stage of the study. The disc space height and the whole lumbar lordotic angle prior to surgery,

Fig. 4 The rotation of the cage in the intervertebral space

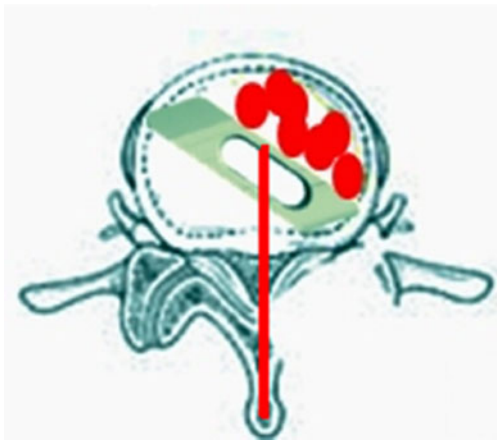

Fig. 5 The rotation of the cage in the intervertebral space

three and six months after surgery, and at the final follow-up were analysed. Fusion status was confirmed for all patients on three-dimensional computed tomography scans and reconstructions and lateral flexion-extension dynamic view radiographs. Solid fusion was judged on radiographs by trabecular bony bridging and fused segments in less than 4 mm of translation or by less than 10° of angular motion between adjacent endplates (Fig. 6) [5]. The disc space height was measured by the distance connecting the line drawn on the upper and lower endplates of the fusion segment and the centre of the superior and inferior endplates. The lumbar lordoric angle was formed by the upper endplate of the L1 verterbral body and the upper endplate of the S1 verterbral body.

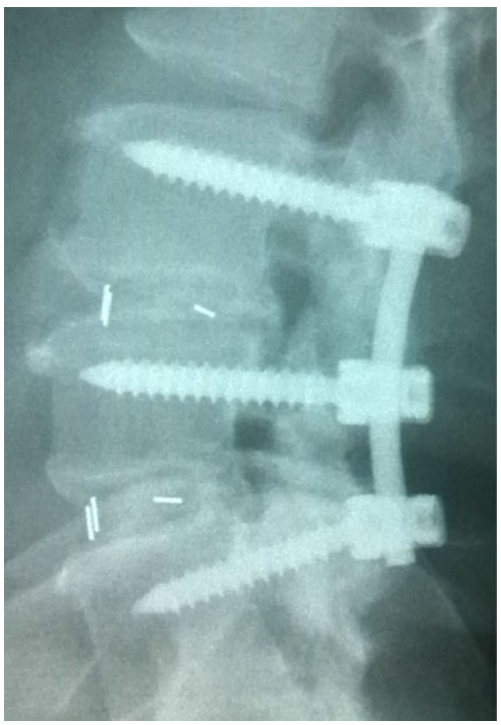

Fig. 6 Lateral radiographs taken 2.5-years postoperatively showing solid fusion with trabecular bony bridging across the adjacent vertebrae

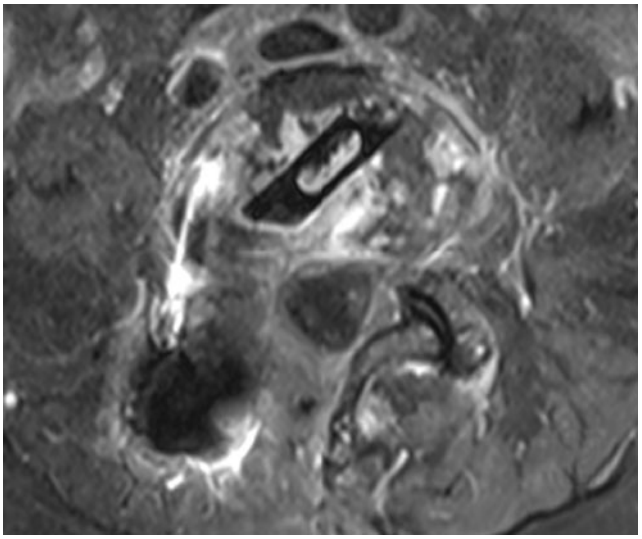

Fig. 7 MRI showing a 65-year-old man with intervertebral disc infection

Statistical analysis

The pre-operative and postoperative clinical results were statistically analysed using the Wilcoxon signed-rank test to compare scores.

Results

There were no peri-operative deaths. Accidental duratomy was not observed. One intervertebral disc infection was observed, which needed reoperation (Fig. 7). There were no metal failures. Clinical outcomes in the mid-term follow-up were measured for all patients according to the criteria used by the VAS and ODI (Table 1). Follow-up data were obtained from the questionnaires forwarded directly to the patients at peri-operative term and postoperative at three and six months, and one, two and three years. The mean pre-operative visual analog scale (VAS) score was 7.02±2.34. At postoperative immediately, as well as at three and six months, and one, two and three years, the VAS scores were assessed as 1.48±0.35, 1.66±0.25, 0.99±0.31, 0.97±0.15, 0.76±0.35, and 0.67±0.18, respectively ($P<0.01$). The mean pre-operative Oswestry Disability Index (ODI) was 51.01±13.22. At postoperative immediately, then at three and six months, and one, two and three years, the ODI scores were assessed as 9.81±2.13, 9.11±2.23, 8.31±2.13, 7.01±3.23, 6.01±1.23, and 5.21±3.83, respectively ($P<0.01$). The significantly improved VAS and ODI occurred between pre-operative and early follow-up assessments with little changes between early and late follow-up ($P<0.01$). The relief of pain during walking, standing, and sitting positions were identified. The disc space height and the whole lumbar lordotic angle were increased (Table 2). The mean pre-operative disc space height was 8.02±2.34 mm. At postoperative immediately, then at three and six months, and one, two and three years the disc space height were assessed as 14.81±2.16 mm, 13.61±2.13 mm, 13.55±1.83 mm, 13.01±2.03 mm, 12.51±1.93 mm, and 12.63±2.46 mm, respectively ($P<0.05$). The mean pre-operative whole lumbar lordotic angle was 20.02±2.12°. At postoperative immediately, then at three and six months, and one, two and three years, the whole lumbar lordotic angle was assessed as 38.02±2.12°, 37.45±1.14°, 37.72±2.16°, 36.72±2.61°,36.52±1.97°, and 35.82±2.72°, respectively ($P<0.05$). Successful fusion was achieved in all patients (Fig. 6).

Discussion

The surgical aim of treatment for symptomatic lumbar canal stenosis is relief of symptoms by adequate neural decompression while preserving much of the anatomy and the biomechanical function of the lumbar spine. Traditional posterior lumbar interbody fusion may have potentially serious consequences due to total laminectomy and resection of all ligament complexes. Total laminectomy and elevation of the multifidus bilaterally with subsequent wide retraction were associated with improvement in 64 % of patients at three to six years after surgery and results deteriorated over time [8]. Besides, complete decompression may not be necessary to achieve symptomatic relief.

Alternatively, unilateral TLIF and bilateral decompression via a midline incision were described. Young et al. [9] first reported the use of contralateral decompression via the vertebral

Table 1 Clinical evaluation using VAS and ODI scores

Scoring system	Pre op	Post op (immediate)	Post op (three months)	Post op (six months)	Post op (three years)
VAS	7.02±2.34	1.48±0.35	1.66±0.25	0.99±0.31	0.67±0.18
ODI	51.01±13.22	9.81±2.13,	9.11±2.23,	8.31±2.13	5.21±3.83

Pre op pre operation, *Post op* post operation, *VAS* visual analogue scale, *ODI* Oswestry disability index

Data presented as mean±SD

Difference significant ($P<0.01$) before and after operation for DSH and LLA at each time point. No significant difference existed after operation at every follow-up

Table 2 Radiological assessments

Measure	Pre op	Post op (immediate)	Post op (3 months)	Post op (6 months)	Post op (3 year)
DSH	8.02±2.34 mm	14.81±2.16 mm	13.61±2.13 mm	13.55±1.83 mm	12.63±2.46 mm
LLA	20.02±2.12°	38.02±2.12°	37.45±1.14°	37.72±2.16°	35.82±2.72°

Pre op pre operation, *Post op* post operation, *DSH* disc space height, *LLA* lumbar lordotic angle

Data presented as mean±SD

Difference significant ($P<0.05$) before and after operation for DSH and LLA at each time point. No significant difference existed after operation at every follow-up

canal in 1988. McCulloch et al. [10] used endoscopy to remove the ligamentum flavum and osteophytes that compressed the nerve root in order to accomplish bilateral decompression in 1991. Cavusoglu et al. [11] concluded in 2007 that for degenerative lumbar spinal stenosis unilateral approaches allowed sufficient and safe decompression of the neural structures and adequate preservation of vertebral stability, which resulted in a highly significant reduction of symptoms and disability, and improved health-related quality of life. Mao et al. [5] concluded that UPSF of the symptomatic side combined with the contralateral intact ligament complex, paraspinal muscle, and facet joint may be seen as the tension band and neutralization system.

But, those studies had not mentioned bilateral decompression via a unilateral approach in the management of two-level lumbar stenosis with instability. In this retrospective study, notably, the unilateral approach preserves the facet joints and neural arch of the contralateral side, leaving the spinous processes and supraspinous/interspinous ligament complex intact, which may protect the nervous structure against posterior scarring, potentially resulting in less postoperative low back pain and a quicker recovery. This study indicated that the ODI scores decreased significantly in both early and late follow-up evaluations and the VAS scores demonstrated significant improvement in late follow-up ($p<0.01$).

Since its first description in 1982, TLIF with a BPSF has become widely accepted as a standard surgical operation for lumbar fusion, achieving fusion rates as high as 90–100 % [12, 13]. However, due to the excessive rigidity of the system, this instrumentation may result in clinically adverse effects, such as device-related osteoporosis, degeneration of adjacent segments and absorption of grafted bone. Furthermore, reoperation rate must be included, plus the reasonable doubt arising from the associated cost benefits of instrumentation.

To compensate for such shortcomings, previous studies reported that the clinical results of UPSF were nearly identical to BPSF for lumbar degenerative disease. Recently, Mao et al. [5] and Zhao et al. [6] demonstrated that TLIF with UPSF was an effective and convenient method of treatment of single-level lumbar degenerative disease. Also, Xue et al. [14] revealed that the fusion rates of double level fusion in the unilateral and bilateral groups were 87.5 % and 91.2 %, respectively. Zhang et al. [7] have suggested that UPSF with reliable anterior support can be used in two-level lumbar disease. Successful fusion was achieved in all patients, due to interbody fusion techniques with a good fusion environment. Taking into account the published articles [5–7, 15] and our study, we suggest that UPSF with diagonal cage-instrumented TLIF can be used in two-level lumbar stenosis with instability. This method is safe, feasible, and effective over the three-year follow-up interval.

The decreased disc space height and the whole lumbar lordotic angle has been reported to be related to poor clinical outcomes [16]. The restoration of lumbar lordosis and balanced sagittal alignment was mandatory to avoid lumbar flat back which could lead to persistent pain and inferior functional outcome. In this retrospective study, the disc space height and the whole lumbar lordotic angle were increased and maintained in all patients, which was why we chose the larger cage that was positioned to support the contralateral part of the anterior column by crossing the midline of the vertebral body (Figs. 4 and 5). Notably, restoration of disc space height and correction of segmental coronal collapse with fusion surgery may be a better choice for better outcome.

Several points should be kept in mind. First, the cage should be large enough to cross the midline of the vertebral body. Second, rotation of the cage in the intervertebral space is required. Third, thorough discectomy and endplate preparation must be performed in order to gain sound interbody fusion.

Despite small case series with retrospective design and the absence of a control group, our study suggests that bilateral decompression via a unilateral approach using UPSF for two-level lumbar stenosis with instability showed good mid-term clinical outcomes. To overcome these limitations, randomized studies with larger study groups and long-term follow up are necessary to further determine the benefits.

Conclusion

This study's data suggest that bilateral decompression via a unilateral approach using unilateral pedicle screw fixation for two-level lumbar stenosis with instability is an effective and less invasive method than with bilateral constructs.

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